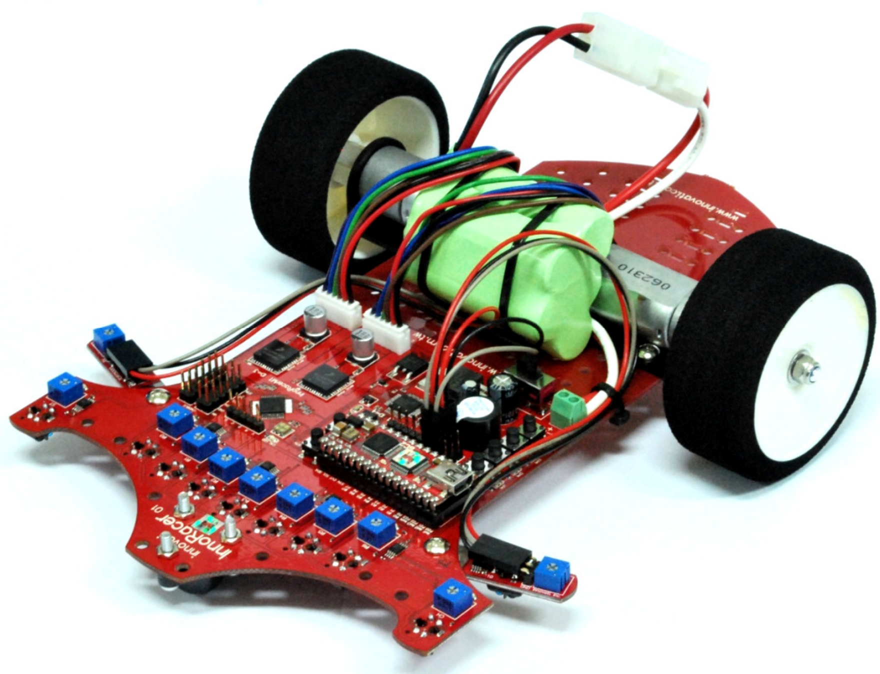
Innoracer™
User's Guide

Document Revision 1.5

June 22, 2011



Passion for innovation

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Errata

We hope that our users will find this user's guide a useful, easy to use and interesting publication, as our efforts to do this have been considerable. Additionally, a substantial amount of effort has been put into this user's guide to ensure accuracy and complete and error free content, however it is almost inevitable that certain errors may have remained undetected. As Innovati will continue to improve the accuracy of its user's guide, any detected errors will be published on its website. If you find any errors in the user's guide please contact us via email service@innovati.com.tw. For the most up-to-date information, please visit our web site at http://www.innovati.com.tw.

Notes:

- This package contains a BASIC Commander® module with instruction on how to use it. Refer to the instructions for the best performance of the item.
- When you replace the battery pack or external power supply, make sure the input voltage is between 6 and 12V to avoid damage to the electronic devices.
- There are two DC brush motors, which require a total or 2A current for normal operation. Insufficient power supply may cause malfunction.
- For a longer testing and operating period, you may use external power supply for the consistent operation performance.
- Commands for the built-in modules are available only for innoBASIC™ Workshop v2.0.2.9 or later.

Table of Contents

Product Overview

Innoracer^{TM} is controlled by the BASIC Commander® and featured with two built-in modules, namely RacerM1 and RacerP1 module. The RacerM1 module is used to sense the track and control the motors to follow the track. The RacerP1 module is used to memorize the route by recording the marks on the curve change, which provides user information to drive the Innoracer^{TM} as fast as possible in later runs. It is specially designed as an entry-level platform for users to learn programming, motor control, line tracking with the unique feature of PID control.

Product Features

- Using the BASIC Commander® as controller, users can modify their program and download to the Innoracer^{TM} via a USB cable.
- Four cmdBUS^{TM} connectors, which allow users to add peripheral modules easily, such as Sonar module to enrich the functionality.
- 7 fixed infrared sensors for track detection.
- To fit different track requirement, 2 position-adjustable infrared sensors for start, stop and curve change marks detection.
- Infrared calibration button to optimize the infrared detection range.
- Reset button to restart the program.
- Variable resistors to change the infrared detection sensitivity, if digital sensor method is employed.
- Four buttons with LEDs for users to define their own functions and indications.
- Built-in buzzer controllable through program or used by RacerP1 module to generate beeps when a curve change mark is detected.
- Built-in RacerM1 module to control two DC motors with 1024 steps of speed.
- Built-in PID control feature in RacerM1 module for better track following capability.
- Scalar parameter to increase the PID numerical resolution for PID fine tune.
- Built-in accelerometer to detect x- and y-axial acceleration forces.
- Built-in RacerP1 module to record up to 256 entries of track section information.
- Track infrared sensing in digital or analog data with commands for data reading.
- Record track information including length, x- and y-axial average and maximum acceleration value, curve radius and direction.
- Hole array on the main board for adjusting the motor position to adapt various curve tracking needs.
- Replacement of motors for better driving performance.

System Diagram

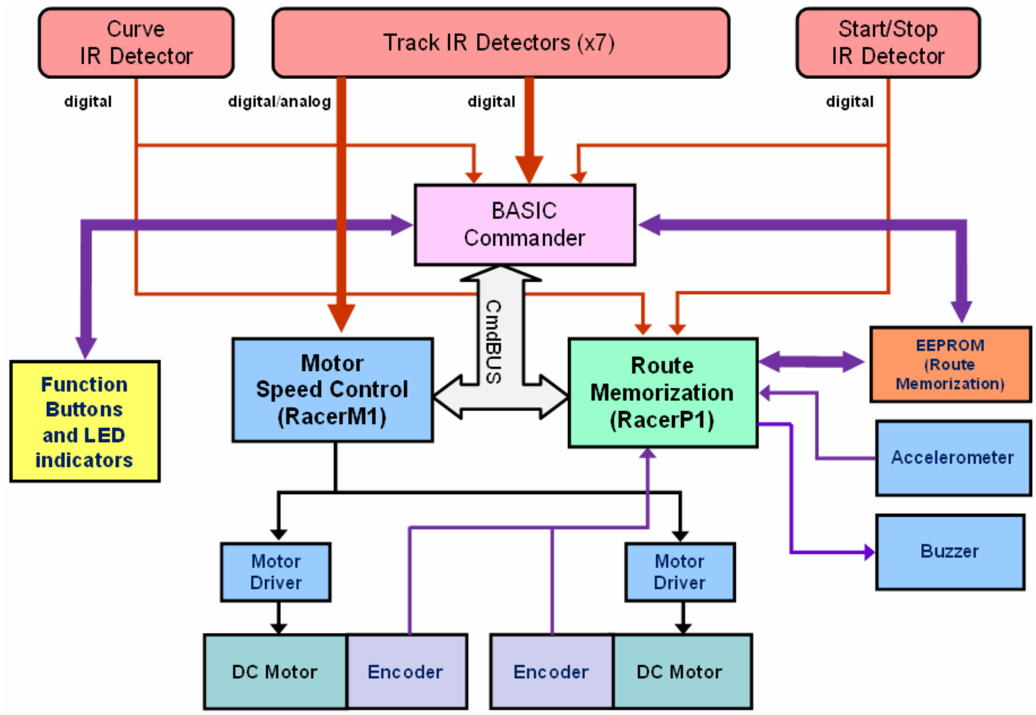


Fig 1 System Diagram

Accessories, such as battery, tires or other irrelevant electronic components are not shown in this system chart.

Key Components

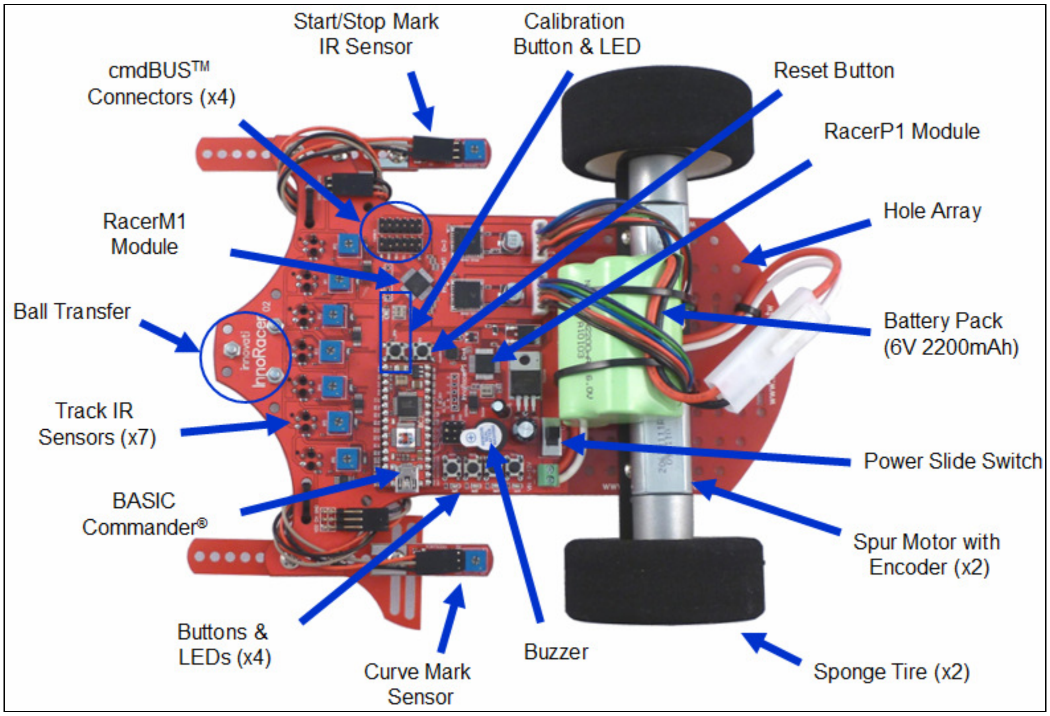


Fig 2 Key Component Placement

Controller – BASIC Commander®

BASIC Commander® is the main controller of the Innoracer™ line tracer. Also known as BC2, the 32-pin version BASIC Commander® has 24 I/O lines suitable for applications which require more I/O lines.

Users can edit and compile their program in the innoBASIC™ Workshop environment and download through a USB cable to the BASIC Commander®. If you are not familiar with the BASIC Commander® system, please refer to the "BASIC Commander® and innoBASIC™ Workshop User's Manual" for more detailed information.

Reflective Infrared Sensors

In the front of the Innoracer™, there are 7 reflective infrared sensors which are used to detect the track. The right side infrared sensor is used to detect the Start or Stop mark, which indicates the beginning and the end of the track. The left side infrared

sensor is used to detect the curve change marks throughout the whole route. The track is divided into segments for route memorization.

Near each infrared sensor, there is a red LED and blue color variant resistor. By turning the screws on variant resistors, you change the threshold of infrared detection. The LED will turn on if the reflection intensity is higher than the threshold, otherwise the LED will turn off. Due to different signal path and threshold settings, the infrared detection by the BASIC Commander® might not be exactly the same as that detected by the RacerM1 module.

Please refer to Tutorial Programs section in the appendix for more information about how to read either digital or analog infrared results.

Infrared Sensors Calibration

Due to the different ambient light and surface material, the infrared sensing results may vary under different situations. To eliminate the variance, calibration is required.

For the Innoracer™, there are two kinds of calibration, digital and analog. The first one is to change the infrared sensors' detection threshold by adjusting the blue variant resistor. Turn clock-wise to increase the threshold level, which means the sensitivity is decreased. Each infrared sensor is accompanied with an LED which will be lit if the infrared intensity detected is higher than the threshold. Note that this calibration process only affects the threshold of LEDs and the infrared detection results read by the BASIC Commander® through its I/Os.

The second one is to press the CAL_BTN button for at least 5 seconds, a red LED near the CAL_BTN will be lit to indicate the calibration in process. Put the Innoracer™ on the track and move it back and forth slowly with all the infrared sensors passing the black and white area of the track several times. Press the CAL_BTN button once again to finish the calibration process and the LED will turn off. The infrared detection range of each infrared sensor is measured and normalized internally for analog infrared intensity sensing use. Note that the analog calibration affects the sensing results of the RacerM1 module only.

Buzzer

The buzzer is mainly used to generate automatically a 0.2 seconds recording beep sound each time a curve change mark is detected during the route memorization process. The buzzer is controlled through the built-in RacerP1 module commands. Please refer to PacerP1 module command set for other buzzer-related commands.

Nevertheless, you may still use the Beep() command to generate beep sounds in your own application.

DC Motors

The Innoracer™ is equipped with two spur brushed DC motors. A Hall Effect sensor is affixed to detect the polarity change of the rotor when rotating, through which you can calculate the distance that each wheel has travelled. This information is used for route memorization.

Note that the DC motor electric brush wears out when spinning against the mechanical parts, the DC motors lifetime is limited. Running at a high speed for a long time will further shorten the life of the DC motors.

Please refer to Tutorial Programs section in the appendix for more information about how to control the DC motors with the given speed parameters.

Accelerometer

The Innoracer™ is equipped with a two-axial accelerometer to measure the proper acceleration in both x- and y-axis, through which you can calculate the curve radius and direction. This information is used for route memorization.

The x-axial acceleration is defined in the lateral axis of the Innoracer™ and the y-axial acceleration is in the longitudinal axis of the Innoracer™. Please refer to the following picture.

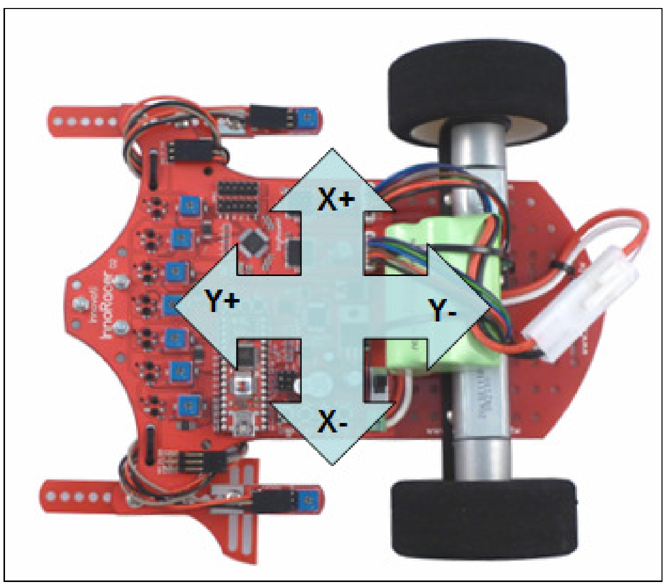


Fig 3 Acceleration Directions

Please refer to Tutorial Programs section in the appendix for more information about how to save the current x- and y-axial acceleration values for calibration at a standstill position and display them in the Terminal Window.

Battery Charger

This charger is designed for 5~10 cells of NiMH battery pack. Do not use this charger to charge other types of battery. Do not use this charger as a power adaptor. An adaptor cable is also provided.

Connect the small end of the cable to the charger and the big end to the battery pack. There is an LED indicator on the charger. The red LED indicates it is in the fast charging mode. When the green is lit, the battery pack is charged about 85% full and the charger will continue to operate in the slow charging mode. The battery pack may reach about 95% full if it is charged in slow charging mode for a longer period.

Fig 4 Battery Charger & Adaptor Cable

Command Set

RacerM1 Module Command Set

The following table lists all the unique commands provided with the RacerM1 Module. Note that essential words in the commands will be written in **bold** type and ***italics*** in bold type. The bold type word must be written exactly as shown, whereas the italic bold type words must be replaced with the user values. Note that the innoBASIC™ language is case-insensitive.

To execute functions related to RacerM1 module, please declare the module ID number as 3 in the program, i.e. **Peripheral *ModuleName* As RacerM1 @ 3**

Command Syntax	Description
Motor Control Commands	
ForwardA(*Speed*) **ForwardB(*Speed*)** **ForwardAB(*SpeedA*, *SpeedB*)** **ForwardDual(*Speed*)** **BackwardA(*Speed*)** **BackwardB(*Speed*)** **BackwardAB(*SpeedA*, *SpeedB*)** **BackwardDual(*Speed*)**	Sets forward/backward speed of motor A, B or both specified by variable ***Speed*** or both ***SpeedA*** and ***SpeedB*** ranging from 0 ~ 1024 respectively. The motor rotating direction is defined from the Innoracer™ viewpoint. Motor A is the left-side wheel motor while Motor B is the right-side wheel motor.
StopA() **StopB()** **StopDual()**	Stops motor A or B or both.
BrakeA() **BrakeB()** **BrakeDual()**	Brakes motor A or B or both.
SetDirA(*Dir*) **SetDirB(*Dir*)** **SetDirAB(*DirA*, *DirB*)** **SetDirDual(*Dir*)**	Sets motor(s) rotation direction of motor A, B or both specified by variable(s) ***Dir*** or both ***DirA*** and ***DirB*** respectively. The returned value 0 for forward and 1 for backward.
SetDCA(*Speed*) **SetDCB(*Speed*)** **SetDCAB(*SpeedA*, *SpeedB*)** **SetDCDual(*Speed*)**	Sets motor(s) rotation speed of motor A, B or both specified by variable(s) ***Speed*** or both ***SpeedA*** and ***SpeedB*** ranging from 0 ~ 1024 respectively. Note that these commands change the speed only, the

	direction remains unchanged.
SetVelA(*Vel*) **SetVelB(*Vel*)** **SetVelAB(*VelA, VelB*)** **SetVelDual(*Vel*)**	Sets speed of motor A, B or both specified by variable ***Vel*** or both ***VelA*** and ***VelB*** ranging from -1024 ~ 1024 respectively. The absolute value stands for speed and positive and negative sign stands for rotation direction.
Motor Speed and Rotation Direction Commands	
GetDCA(*Speed*) **GetDCB(*Speed*)** **GetDCAB(*SpeedA*, *SpeedB*)**	Gets forward speed of motor A, B or both and stores in variable ***Speed*** or both ***SpeedA*** and ***SpeedB***. The returned value(s) ranges from 0 ~ 1024.
GetDirA(*Dir*) **GetDirB(*Dir*)** **GetDirAB(*DirA*, *DirB*)**	Gets rotation direction of motor A, B or both and stores in variable ***Dir*** or both ***DirA*** and ***DirB***. The returned value is 0 for forward and 1 for backward.
GetVelA(*Vel*) **GetVelB(*Vel*)** **GetVelAB(*VelA*, *VelB*)**	Gets speed of motor A, B or both and stores in variable ***Vel*** or both ***VelA*** and ***VelB*** ranging from -1024 ~ 1024 respectively. The absolute value stands for speed and the positive and negative sign stands for rotation direction.
Infrared Sensing Commands	
GetIR(*IR*)	Gets the digital (1 or 0) values of all seven infrared sensors, combining in one data byte with value ranging from 0 ~127 and stores in variable ***IR***. The bit 0 is the right-most IR sensor and the bit 6 is the left-most IR sensor. The bit 7 is not used always read as 0.
GetAnalogIR(*ID*, *IR*)	Gets the infrared intensity value ranging from 0 ~4095 and stores in variable ***IR***. The infrared sensor unit is specified by variable ***ID*** ranging from 0 ~ 6.
NormStart(*Mode*)	Sets the normalization calibration mode by the variable ***Mode*** ranging from 0 ~4. 0: Calibrating until calibration button pressed. 1: Calibrating for 10 seconds. 2: Calibrating for 20 seconds. 3: Calibrating for 30 seconds. 4: Calibrating for 60 seconds.
GetNorm (*ID*, *Min*, *Max*)	Gets the minimum and maximum infrared intensity of specified IR sensor during calibration and stores them in variable ***Min*** and ***Max***, which will be used

	by the RacerM1 module for internal normalization. The IR sensor is specified by variable ***ID*** ranging from 0 ~ 6. The infrared intensity value ranges from 0 ~ 4095.
SetIRThreshold(*Rate*)	Sets the threshold percentage value specified by variable ***Rate*** ranging from 0 ~ 100 of infrared intensity range. You can use this setting to change the infrared sensibility. Take a ***Rate*** value 60 for example, if the infrared intensity is stronger than the 60%, say 85%, of the possible infrared range, it will be regarded as logic 1 meaning a white track is detected, otherwise logic 0 meaning white track is not detected.
GetIRThreshold(*Rate*)	Retrieves the threshold percentage value and saves in variable ***Rate***. The value ranges from 0 ~ 100. Please refer to above command for more details.
SetIRMode(*Mode*)	Sets the IR sensors track detection method by variable ***Mode*** with value 0 for digital mode or 1 for analog mode. The default value is 0 for digital mode.
GetIRMode(*Mode*)	Gets the IR sensors track detection method setting and stores in variable ***Mode***, of which the value 0 is for digital mode or 1 for analog mode.
PID Commands	
SetP(*Val*)	Sets the P, I or D parameter by variable ***Val***. The value ranges from 0 ~ 255.
SetI(*Val*)	
SetD(*Val*)	
GetP(*Val*)	Retrieves the P, I or D parameter and stores in variable ***Val***. The value ranges from 0 ~ 255.
GetI(*Val*)	
GetD(*Val*)	
SetScalar(*Val*)	Sets the PID parameters scalar by variable ***Val*** ranging from0 ~ 32 as a multiple of the original PID values. However, if the given scalar is greater than 32, the PID control function will not be activated.
GetScalar(*Val*)	Retrieves the PID Scalar setting and stores in variable ***Val*** ranging from 0 ~ 255. Please refer to the above command for more details about scalar.
SetErrScale(*Err1*, *Err2*, *Err3*, *Err4*, *Err5*, *Err6*)	Sets the error values by variables ***Err1*** through ***Err6*** as feedback for PID control for various IR detection

	situations. Each of error value ***Err1*** ~ ***Err6*** ranges from 0 ~ 127.
GetErrScale (*Err1*, *Err2*, *Err3*, *Err4*, *Err5*, *Err6*)	Retrieves the error values settings and stores them in variables ***Err1*** through ***Err6*** as feedback for PID control under various IR detection situations. Each of ***Err1*** ~ ***Err6*** ranges from 0 ~ 127.
Speed Setting and Control Commands	
SetSpdCtrlA(*SpdMin*, *SpdMax*)	Sets the minimum and maximum speed of motor A or B by variables ***SpdMin*** and ***SpdMax*** for PID speed control. ***SpdMin*** and ***SpdMax*** range from -1024 ~ 1024. ***SpdMax*** must be greater than ***SpdMin***. If the given value of ***SpdMax*** is not greater than ***SpdMin***, the command will be ignored.
SetSpdCtrlB(*SpdMin*, *SpdMax*)	
GetSpdCtrlA(*SpdMin*, *SpdMax*)	Retrieves the minimum and maximum speed settings of motor A or B for PID speed control and stores in variables ***SpdMin*** and ***SpdMax***. ***SpdMin*** and ***SpdMax*** range from -1024 ~ 1024.
GetSpdCtrlB(*SpdMin*, *SpdMax*)	
SetStraight(*SpeedA*, *SpeedB*)	Sets the straight line speed of motor A and B by variables ***SpeedA*** and ***SpeedB*** ranging from -1024 ~ 1024 for PID speed control.
GetStraight(*SpeedA*, *SpeedB*)	Retrieves the straight line speed setting of motor A and B and stores in variables ***SpeedA*** and ***SpeedB*** ranging from -1024 ~ 1024 for PID speed control.
SpdCtrlOn(*Mode*)	Starts the PID speed control in mode specified by variable ***Mode***. 0: Any change of speed settings will terminate the PID speed control automatically. 1: PID control continues regardless of the speed settings change.
SpdCtrlOff()	Stops the PID speed control. The Innoracer™ will run with the last given speed settings.
GetMax(*SpeedA*, *SpeedB*)	Gets the maximum speed of motor A and B during speed control and stores them in ***SpeedA*** and ***SpeedB***, which ranges from -1024 ~ 1024.
GetMin(*SpeedA*, *SpeedB*)	Gets the minimum speed of motor A and B during speed control and stores them in ***SpeedA*** and ***SpeedB***, which ranges from -1024 ~ 1024.
ClearRec()	Clears all the recorded track section information.

SetCtrlFreq(*Period*)	Sets the speed control frequency by variable ***Period***, ranging from 0 ~ 100 of unit ms. If the given value exceeds the maximum speed control capability, the maximum speed will be used. Period with value 0 is equal to value 1.
GetCtrlFreq(*Period*)	Retrieves the speed control frequency setting and stores in variable ***Period***, ranging from 0 ~ 100 of unit ms.
Miscellaneous Commands	
SetCrossMode(*Mode*)	Sets cross road running behavior by variable ***Mode***, ranging from 0 ~ 2. 0: keeps running. 1: stops. 2: brakes.
GetCrossMode(*Mode*)	Retrieves cross road behavior setting and stores in variable ***Mode***, ranging from 0 ~ 2.
SetOutsideMode(*Mode*)	Sets the tracer run-away behavior by variable ***Mode***, ranging from 0 ~ 2. 0: keeps running. 1: stops. 2: brakes.
GetOutsideMode(*Mode*)	Retrieves the run-away behavior setting and stores in variable ***Mode***, ranging from 0 ~ 2.
SetLineColor(*Color*)	Sets the track color by variable ***Color***. Value 0 for white and 1 for black color. The default value is 0 for white track color.
GetLineColor(*Color*)	Retrieves the track color setting and stores in variable ***Color***. Value 0 for white and 1 for black color.

RacerP1 Module Command Set

The following table lists all the unique commands provided with the RacerP1 Module. Note that essential words in the commands will be written in **bold** type and ***italics*** in bold type. The bold type word must be written exactly as shown, whereas the italic bold type words must be replaced with the user values. Note that the innoBASIC™ language is case-insensitive.

To execute functions related to RacerP1 module, please declare the module ID number as 4 in the program, i.e. **Peripheral *ModuleName* As RacerP1 @ 4**

Command Syntax	Description
Motor Tachometer Commands	
bStatus **= TACHInR(*TACH*)** ***bStatus*** **= TACHInL(*TACH*)**	Gets the right or left motor Hall Effect pulse count detected in each complete 125ms period and stores it in variable ***TACH***, ranging from 0 ~ 65535 and returns the pulse counting reading status in variable ***bStatus***. If the count has not been read, value 1 is returned, otherwise value 0 is returned. Note that the count value is stored in an internal buffer to be read by the commands If you can not read the count value stored in the buffer within the 125ms interval, the internal data buffer will be overwritten by the new data.
bStatus **= TACHInDual(*TACHL*, *TACHR*)**	Gets both the right and left motor Hall Effect pulse counts detected in each complete 125ms period and stores them in variable ***TACHL*** and ***TACHR***, and returns the pulse counting status in variable ***bStatus***, ranging from 0 ~ 3. 0: both of the counts have been read 1: left motor has not been read 2: right motor has not been read 3: both of the counts have not been read Note that the count values are stored in internal buffers to be read by the commands separately. If you cannot read the count value stored in the buffer within the 125ms interval, both the internal data buffers will be overwritten by the new data.
Route Recording Commands	
StartRec(*Mode*)	Starts to record the track information. If ***Mode*** has value 1, then the information will be stored in EEPROM, which can be retrieved later for route memorization, otherwise, if it has value 0, only current recorded section information is available, which will be overwritten by the next track section information. The recording beep sound at each

	curve change is generated in both modes.
StopRec()	Stops recording the track information. The recording beep sound will not be generated.
GetRecStatus(*Status*)	Gets the track recording status and stores in variable ***Status***. 0: not recording or recording finished. 1: recording, but has not passed the start mark. 2: recording and passed the start mark.
ClrTotalLen()	Clears the total length of the track in tachometer counts unit.
GetRateRL(*Rate*)	Gets the right wheel and left wheel tachometer pulse count ratio multiplied by 65536 and saves in variable ***Rate*** ranging from 0 ~ 4294967295.
GetSecCnt(*Cnt*)	Gets the curve change mark counts and stores in variable ***Cnt***, ranging from 0 ~ 255.
GetSecLen(*Num*, *LengthL*, *LengthR*)	Gets the traveled length of right and left wheel in section ***Num***, ranging from 0 ~ 255 and stores the lengths in variable ***LengthL*** and ***LengthR*** ranging from 0 ~ 4294967295. The length is expressed with tachometer counts as the unit.
GetCurSecTACH(*LengthL*, *LengthR*)	Gets the traveled length of right and left wheel of current section and stores the lengths in variable ***LengthL*** and ***LengthR*** ranging from 0 ~ 4294967295. The length is expressed with tachometer counts as the unit. Note that this command takes effect if track recording mode is activated.
GetTotalLen(*LengthL*, *LengthR*)	Gets the till current total traveled length of right and left wheel and stores the lengths in variable ***LengthL*** and ***LengthR*** ranging from 0 ~ 4294967295. The length is expressed with tachometer counts as the unit. Note that this command takes effect if track recording mode is activated.
Counter Commands	
SetTimer(*Freq*)	Sets the timer time-out frequency by variable ***Freq***, ranging from 0 ~ 1000 in 10 Hz unit. To start the timer, a low to high transient needs to be issued by P12 of BASIC Commander®. When the timer times out, a high level signal can be issued and can be

	read from P13 of BASIC Commander®. To clear the P13 high level signal, a low to high transient needs to be issued again by P12 of BASIC Commander®.
GetTimer(*Freq*)	Retrieves the timer time-out frequency setting and stores in variable ***Freq***, ranging from 0 ~ 1000 in 10 Hz unit.
Infrared Sensing Command	
GetIR(*IR*)	Gets the start/stop and curve change marks detect result and stores in variable ***IR*** ranging from 0 ~ 3, where bit 0 stands for the start/stop mark and bit 1 for the curve change mark. Take the white marks for example, if start/stop mark or curve change mark is detected, their corresponding bit will be 1.
Accelerometer Commands	
GetG(*Gx*, *Gy*)	Gets x- and y-axial acceleration values ranging from -2048 ~ 2047 and stores them in variables ***Gx*** and ***Gy***.
GetMaxG(*Gx*, *Gy*)	Gets the maximum x- and y-axial acceleration values ranging from -2048 ~ 2047 and stores them in variables ***Gx*** and ***Gy***. Note that this command takes effect if track recording mode is activated.
GetAvgG(*Gx*, *Gy*)	Gets the average x- and y-axial acceleration values ranging from -2048 ~ 2047 and stores them in variables ***Gx*** and ***Gy***. Note that this command takes effect if track recording mode is activated.
GetSecMaxG(*Num*, *Gx*, *Gy*)	Gets the maximum x- and y-axial acceleration values ranging from -2048 ~ 2047 of route section specified by variable ***Num*** ranging from 0 ~ 255 and stores them in variables ***Gx*** and ***Gy***. Note that this command takes effect if track recording mode is activated.
GetSecAvgG(*Num*, *Gx*, *Gy*)	Gets the average x- and y-axial acceleration values ranging from -2048 ~ 2047 of route section specified by variable ***Num*** ranging from 0 ~ 255 and stores them in variables ***Gx*** and ***Gy***. Note that this command takes effect if track recording mode is activated.
SaveCur0G()	Saves current x- and y-axial acceleration values

	detected as the offsets of a standstill position.
Load0G(*Gx*, *Gy*)	Gets the x- and y-axial acceleration offset values stored for standstill position and stores them in variables ***Gx*** and ***Gy*** ranging from -2048 ~ 2047.
Set0G(*Gx*, *Gy*)	Sets the x- and y-axial acceleration offset values for standstill position by variables ***Gx*** and ***Gy*** ranging from -2048 ~ 2047.
Curve Commands	
GetRadius(*Dir*, *Radius*)	Gets the curve direction and radius of the most recently recorded track section and stores them in variables ***Dir*** and ***Radius***. The return value of ***Dir*** will be 0 or 1 which stands for CCW and CW turning respectively. The value of ***Radius*** ranges from 0 ~ 4294967295 in tachometer counts unit. Note that this command takes effect if track recording mode is activated, otherwise it returns 0.
GetSecRadius(*Num*, *Dir*, *Radius*)	Gets the curve direction and radius of the track section specified by variable ***Num*** ranging from 0 ~ 255, and stores them in variables ***Dir*** and ***Radius***. The return value of ***Dir*** will be 0 or 1 which stands for CCW and CW turning respectively. The value of ***Radius*** ranges from 0 ~ 4294967295 in tachometer counts unit. If the given section number exceeds the maximum number of sections, unexpected values will be returned.
Miscellaneous Commands	
Beep()	Generates a beep sound of 0.2 second duration.
AutoBeep(*Mode*)	Enables or disables Auto Beep function by variable ***Mode***. When a curve change mark is detected, a 0.2 ms beep sound is generated. ***Mode*** with value 0 will disable auto beep function, while value 1 will enable the auto beep function. Other values will be ignored.
SetCrossTime(*Time*)	Sets the cross track detect interval in variable ***Time***. If both of the curve and start/stop IR sensors detect the marks within ***Time*** ms interval, it will be regarded as a cross track instead of a curve or start/stop mark. ***Time*** ranges from 0 ~ 250 ms. It

<table>
<tr><td></td><td>needs to be initialized in the program.</td></tr>
<tr><td>GetCrossTime(Time)</td><td>Retrieves the cross track detect interval and stores in variable Time. The value ranges from 0 ~ 250 ms.</td></tr>
<tr><td>SetLineColor(Color)</td><td>Sets the track line color in variable Color. 0: white line; 1: black line. Other values will be ignored. The default value is 0 at each program reset.</td></tr>
<tr><td>GetLineColor(Color)</td><td>Retrieves the track line color and saves in variable Color. 0: white line; 1: black line.</td></tr>
<tr><td>EnWP()</td><td rowspan="2">Enables or disables EEPROM Write Protection function. The RacerP1 module uses an on-board EEPROM to store the recorded information, including the left and right tachometer counts, maximum and average acceleration in both x- and y-direction, curvature radius and direction, etc. However, this EEPROM is also accessible directly by the BASIC Commander® through its I/Os. To prevent from data being over-written accidentally, commands are provided for EEPROM management.</td></tr>
<tr><td>DisWP()</td></tr>
</table>

Appendix A --- Tutorial Programs

To help you be familiar with the Innoracer™, some tutorial programs with brief introduction are provided in this section. You can also find the tutorial examples in the DVD.

To maintain the tutorial programs free of error and up-to-date, they are subject to change without notice. For new users, who are not familiar with the BASIC Commander®, please refer to the "BASIC Commander® and innoBASIC™ Workshop User's Manual" for more detailed information.

Ex. 1 --- Light the LEDs Sequentially

This program gives the basics of lighting the LEDs. There are 4 LEDs on the Innoracer™ board, they can be controlled via pin 20, 21, 22 and 23 of the BASIC Commander® I/Os.

```
Sub Main()
   Dim bLED As Byte     ' variable for LED pin number
   Do           ' infinite do loop
      For bLED=20 To 23        ' from pin 20 through pin 23
         High bLED     ' turn on LED
         Pause 500     ' pause for 0.5 second
         Low bLED      ' turn off LED
         Pause 500     ' pause for 0.5 second
      Next
   Loop
End Sub
```

Ex. 2 --- Light the LEDs If Buttons Pressed

In addition to the 4 LEDs, there are also 4 buttons on the innoracer® board, they can be accessed via pin 16, 17, 18 and 19 of the BASIC Commander® I/Os. If any one of the 4 buttons is pressed, the corresponding LED will be lit.

```
#DEFINE BTN_1 16
#DEFINE BTN_2 17
#DEFINE BTN_3 18
#DEFINE BTN_4 19

Sub Main()
   Dim bCnt1 As Byte = 0
   Dim bCnt2 As Byte = 0
   Dim bCnt3 As Byte = 0
   Dim bCnt4 As Byte = 0

BEGIN:
   Pause 10   ' 10 ms debounce time

   ' Detect buttons and jump to labels if pressed
   Button BTN_1,0,255,20,bCnt1,1,BLINK_LED1
   Button BTN_2,0,255,20,bCnt2,1,BLINK_LED2
   Button BTN_3,0,255,20,bCnt3,1,BLINK_LED3
   Button BTN_4,0,255,20,bCnt4,1,BLINK_LED4
   Goto BEGIN   ' loop from beginning

BLINK_LED1:
   TurnOnLED(20)
   Goto BEGIN
BLINK_LED2:
   TurnOnLED(21)
   Goto BEGIN
BLINK_LED3:
   TurnOnLED(22)
   Goto BEGIN
BLINK_LED4:
   TurnOnLED(23)
   Goto BEGIN
End Sub

Sub TurnOnLED(bLED As Byte)
   High bLED       ' turn on LED
   Pause 500       ' wait for 0.5 seconds
```

```
   Low bLED         ' turn off LED
   Pause 500        ' wait for 0.5 seconds
End Sub
```

Ex. 3 --- Motor Control Using RacerM1

There are two DC motors on the innoracer® board. This program gives the basics of DC motor control using our featured commands available through the RacerM1 module. This program shows how to control the DC motors with the given speed parameters through the RacerM1 module. To prevent the Innoracer™ from running away, please keep it off the ground when executing the program.

Note that the DC motor electric brush wears out when spinning against the mechanical parts, the DC motors lifetime is limited. Running at a high speed for a long time will further shorten the life of the DC motors.

```
Peripheral myM As RacerM1 @ 3   ' declare Motor Control Module ID
Sub Main()
   Dim bKey As Byte         ' variable for stop or brake
   Dim iVelL, iVelR As Integer  ' velocity of left and right motor

   Do           ' infinite loop
      Debug CLS      ' clear terminal window
      Debugin "Enter Left Motor Speed (-1024~1024): ", iVelL
      Debug iVelL, CR
      Debugin "Enter Right Motor Speed (-1024~1024): ", iVelR
      Debug iVelR, CR

      myM.SetVelAB(iVelL, iVelR)    ' set parameters to RacerM1 module

      Debugin "Enter how to stop (0: Stop, 1: Brake): ", bKey
      Debug bKey, CR

      If bKey=0 Then
         myM.StopDual()        ' stop the car
      Else
         myM.BrakeDual()       ' brake the car
      End If
```

```
      Keyin "Any key to continue testing", %CHR bKey
   Loop
End Sub
```

Ex. 4 --- Detection with Infrared Sensors

There are total 9 infrared sensors used by the innoracer®. Seven of them are used to detect the position of the track. The remaining two are used to detect the Start and Stop mark on the right-hand side and the curve change marks on the left-hand side. This program shows how to read the infrared detection results and displays them in the Terminal Window.

Note that the infrared sensors calibration is advised. Please check the "Infrared Sensors Calibration" section for more details.

```
Sub Main()
   Dim bIR,ST,CH As Byte    ' variables for IR intensity values

   Debug  CLS                   ' clear Terminal Window
   Debug "Route IR Value: ",CR  ' text out to Terminal Window
   Debug "   ST IR Value: ",CR  '
   Debug "   CH IR Value: "     '

   ' infinite loop, to detect and show IR intensity values

   Do
      bIR = Readport(0)            ' read port 0 (i.e. bit 0 to bit 7)
      bIR = bIR And &H7F
      ST=in(11)                  ' read bit 11
      CH=in(7)                    ' read bit 7
      Debug CSRXY(17,1), %BIN bIR      ' display bit 0~7 in binary
format
      Debug CSRXY(17,2), %BIN ST        ' display bit 11
      Debug CSRXY(17,3), %BIN CH       ' display bit 7
   Loop
End Sub
```

Ex. 5 --- Tracking with 3 Infrared Sensors

There are 7 infrared sensors on the Innoracer™, which can be used to detect the position of the track. This program starts with an easier way to detect the track by using the central 3 of them. The ERR values are for tutorial purpose only. You may try to find your own ERR value as the feedback for better tracking performance.

```
Peripheral myM As RacerM1 @ 3    ' declare module ID
#DEFINE CEN_SPD_R 170       ' right wheel central speed
#DEFINE CEN_SPD_L 170       ' left wheel central speed
#DEFINE ERR1 80     ' error values
#DEFINE ERR2 50     '
#DEFINE ERR3 30     '
#DEFINE ERR4 0      '
#DEFINE ERR5 -30    '
#DEFINE ERR6 -50    '
#DEFINE ERR7 -80    '

Sub Main()
   Dim IR2,IR3,IR4,Sensor As Byte  ' detection results
   Dim R,L,Err As Integer         ' right/left speed and error

   Pause 2000               ' wait for 2 seconds

   Do        ' infinite Loop
      IR2 = In(2)          ' read pin 2 (IR2) IR value
      IR3 = In(3)          ' read pin 3 (IR3) IR value
      IR4 = In(4)          ' read pin 4 (IR4) IR value

      Sensor = (100 * IR4) + (10 * IR3) + IR2

      Select Sensor     ' error look-up table
         Case 011
            Err = ERR2
         Case 001
            Err = ERR3
         Case 101
            Err = ERR4
         Case 100
```

```
            Err = ERR5
        Case 110
             Err = ERR6
        Case 111
            If Err<0 Then      ' line out of range
                Err = ERR7     ' set the biggest error
            Elseif Err>0 Then  ' same direction As
                Err = ERR1      ' previous error
              End If'
        Case 000
             Err = ERR4
    End Select

    R = CEN_SPD_R + Err           ' adjust right/left
    L = CEN_SPD_L - Err           ' wheel speed

    If R>1024 Then             ' right wheel speed limit
        R = 1024               '
    Elseif R<-1024 Then        '
         R = -1024             '
    End If

    If L>1024 Then             ' left wheel speed limit
        L = 1024               '
    Elseif L<-1024 Then        '
         L = -1024             '
    End If

    myM.SetVelAB(L,R)     ' change speed accordingly
  Loop
End Sub
```

Ex. 6 --- Tracking with 7 Infrared Sensors

In this program, we use all of the 7 infrared sensors on the Innoracer™ for tracking, For smaller curve radius, 3 LEDs might not be enough to follow the track. In this situation, 7 infrared sensors will be useful. The ERR values are for tutorial purpose

only. You may try to find your own ERR value as the feedback for better tracking performance.

```
Peripheral myM As RacerM1 @ 3    ' declare module ID
#DEFINE CEN_SPD_R 210   ' right wheel central speed
#DEFINE CEN_SPD_L 210   ' left wheel central speed
#DEFINE ERR1 111    ' error values
#DEFINE ERR2 71
#DEFINE ERR3 45
#DEFINE ERR4 21
#DEFINE ERR5 9
#DEFINE ERR6 3
#DEFINE ERR7 0
#DEFINE ERR8 -3
#DEFINE ERR9 -9
#DEFINE ERR10 -21
#DEFINE ERR11 -45
#DEFINE ERR12 -75
#DEFINE ERR13 -111

Sub Stop()          ' subroutine to stop motors
   myM.BrakeDual()
End Sub

Sub Main()
   Dim Sensor As Byte     ' detection results
   Dim R,L,Err As Integer  ' right/left speed and error

   Pause 2000             ' wait for 2 seconds

   Do                     ' infinite Loop
      Sensor=Readport(0)       ' read port 0 (P0~P7)
      Sensor=Sensor And &H7F  ' mask unused P7 data

      Select Case Sensor     ' error look-up table
         Case &B0111111   :   Err = ERR1
         Case &B0011111   :   Err = ERR2
         Case &B1011111   :   Err = ERR3
```

```
        Case &B1001111   :  Err = ERR4
        Case &B1101111   :  Err = ERR5
        Case &B1100111   :  Err = ERR6
        Case &B1110111   :  Err = ERR7
        Case &B1110011   :  Err = ERR8
        Case &B1111011   :  Err = ERR9
        Case &B1111001   :  Err = ERR10
        Case &B1111101   :  Err = ERR11
        Case &B1111100   :  Err = ERR12
        Case &B1111110   :  Err = ERR13
        Case &B1111111       ' out of tracking range
            Stop()           ' stop motors
            Goto FINISH      ' terminate the program
    End Select

    R = CEN_SPD_R + Err     ' adjust right wheel speed
    L = CEN_SPD_L - Err     ' adjust left wheel speed

    If R>1024 Then         ' right wheel speed limit
        R = 1024           '
    Elseif R<-1024 Then    '
        R = -1024          '
    End If                 '

    If L>1024 Then         ' left wheel speed limit
        L = 1024           '
    Elseif L<-1024 Then    '
        L = -1024          '
    End If                 '

    myM.SetVelAB(L,R)      ' change speed
  Loop
FINISH:
End Sub
```

Ex. 7 --- Analog Infrared Readings

This program shows how to get the analog readings of the seven infrared sensors. They will be displayed in the Terminal Window. It is handy way to check your infrared sensors if you encounter infrared sensing problem.

```
Peripheral myM As RacerM1 @ 3
Sub Main()
    Dim i As Byte       ' Infrared sensor number
    Dim wIR As Word     ' returned analog value

    Debug CLS           ' clear Terminal Window
    Do                  ' infinite loop
        For i=0 To 6                        ' from IR 0~6
            MyM.GetAnalogIR(i,wIR)          ' get analog data
            Debug CSRXY(1,i),%DEC6R wIR,CR  ' display
        Next
    Loop
End Sub
```

Ex. 8 --- Normalization Basics

In the previous exercise, you should have noticed that all the infrared sensors return readings with different value ranges. The raw data needs to be normalized to be manipulated easily in the program. The normalization is accomplished during the calibration process by the RacerM1 module, which employs the min-max normalization method to perform a linear transformation on the original data range to new data range. This program shows how the normalization is done within the RacerM1 module during calibration process.

```
Peripheral myM As RacerM1 @ 3
Sub Main()
    Dim i As Byte       ' Infrared sensor number
    Dim aMin(6),aMax(6),aSec(6) As Word ' variable arrays
    Dim dwIR,dwNorm As Dword            ' analog and calibrated values

    Debug CLS
```

```
    For i=0 To 6                        ' from IR 0~6
        myM.GetNorm(i,aMin(i),aMax(i))  ' get max/min of calibration
        aSec(i) = aMax(i) - aMin(i)     ' calculate the range
    Next

    Do                 ' infinite loop
        For i=0 To 6     ' from IR 0~6
            MyM.GetAnalogIR(i,dwIR)     ' get the raw data
            dwNorm = (100*(dwIR-aMin(i)))\aSec(i)  ' normalization
            Debug CSRXY(1,i+1),%DEC7R dwIR         ' original values
            Debug CSRXY(8,i+1),%DEC7R dwNorm       ' normalized values
        Next
    Loop
End Sub
```

Ex. 9 --- Track Detection Using Polynomial Interpolation

In the previous "Tracking with 7 Infrared Sensors" exercise, we use the discrete values, for instance, 1, 2, 3 to describe the location of the track. However, for more precise PID control, we need higher resolution feedback of the track position. To achieve this, we employ the polynomial interpolation method in the RacerM1 module. Nevertheless, to learn more about the polynomial interpolation basics, we implement the polynomial interpolation directly in the main program for tutorial purposes.

Here we give a brief explanation of how it works. When the Innoracer™ is running over the track, the infrared reflection intensity detected by the sensors resembles a normal distribution bell shape. However, the normal distribution function is not easy to solve, so we use the central part of a parabola to resemble the normal distribution. The parabola is represented by the polynomial $y=ax^2+bx+c$. From the infrared readings of 7 IR sensors, we use the 3 highest infrared readings to solve the polynomial and to get the coefficients a, b and c. The vertex of a parabola indicates the center of the track, which can be calculated by the formula $x=-b/2a$ with the highest IR sensor as the origin of the coordinates.

Note that to solve the polynomial we need 3 highest readings, which are more significant to resemble the actual intensity distribution precisely. However, if the highest reading comes from the rightmost or leftmost IR sensor, the third highest reading infrared sensor next to it does not exist. In that case we must take the next

highest (the fourth) infrared sensor reading to solve the polynomial. Unfortunately, the accuracy of resembling with a parabola decreases rapidly if the track is getting closer to the 1st and 7th infrared sensors.

```
Peripheral myM As RacerM1 @ 3    ' declare module ID
Sub Main()
    Dim i As Byte           ' loop index
    Dim bNum(2) As Byte      ' max IR IDs
   Dim wARY(13) As Word
    Dim dwNorm(6) As Dword  ' calibrated values
    Dim dwVal(2) As Dword   ' max IR value buffer
    Dim wMax As Word        ' calibrated max value
    Dim wMin As Word        ' calibrated min value
    Dim wRng As Word        ' calibrated range value
    Dim dwIR As Dword       ' IR value

    Dim fY1,fY2,fY3 As Float
    Dim fA,fB As Float      ' polynominal coeff.
    Dim fX As Float        ' track location

    Debug CLS
    Debug "Track Position: "

start:
    For i=0 To 6                   ' 7 IR sensors
        myM.GetNorm(i,wMin,wMax)   ' get calibrated min/max values
        wARY(i)=wMax-wMin          ' save min-max range
        wARY(i+7)=wMin             ' save min value
    Next

    Do
        dwVal(0)=0      ' clear 3 max IR buffer
        dwVal(1)=0      '
        dwVal(2)=0      '

        For i=0 To 6
            MyM.GetAnalogIR(i,dwIR)   ' get current IR value
            wRng=wARY(i)              ' retrieve range
```

```
        wMin=wARY(i+7)            ' retrieve min value
        dwNorm(i)=(100*(dwIR-wMin))\wRng    ' normalization

      If dwNorm(i)>dwVal(0) Then        ' sort to get the
            dwVal(2)=dwVal(1)           ' 3 highest normalized
            dwVal(1)=dwVal(0)           ' IR values and IDs
            dwVal(0)=dwNorm(i)          '
            bNum(2)=bNum(1)             '
            bNum(1)=bNum(0)             '
            bNum(0)=i                   '
        Elseif dwNorm(i)>dwVal(1) Then  '
            dwVal(2)=dwVal(1)           '
            dwVal(1)=dwNorm(i)          '
            bNum(2)=bNum(1)             '
            bNum(1)=i                   '
        Elseif dwNorm(i)>dwVal(2) Then  '
            dwVal(2)=dwNorm(i)          '
            bNum(2)=i                   '
        End If                          '
    Next
                  '
    If bNum(0)=bNum(1)+1 Then           ' track at right side
        If bNum(0)<6 Then               ' highest IR ID 0~5
            fX=bNum(0)
            fY1=Dword2float(dwVal(1))
            fY2=Dword2float(dwVal(0))
            fY3=Dword2float(dwNorm(bNum(0)+1))  ' take left side IR
        Else
            fX=5
            fY1=Dword2float(dwNorm(4))  ' no more leftmost IR
            fY2=Dword2float(dwVal(1))   ' take 4th IR instead
            fY3=Dword2float(dwVal(0))   ' to solve polynomial
        End If

    Elseif bNum(0)=bNum(1)-1 Then      ' track at left side
        If bNum(0)>0 Then              ' highest ID 1~6
            fX=bNum(0)
            fY1=Dword2float(dwNorm(bNum(0)-1)) ' take right side IR
```

```
                fY2=Dword2float(dwVal(0))
                fY3=Dword2float(dwVal(1))
            Else
                fX=1
                fY1=Dword2float(dwVal(0))   ' no more rightmost IR
                fY2=Dword2float(dwVal(1))   ' take 2nd IR instead
                fY3=Dword2float(2)          ' to solve polynomial
            End If
        End If

            fA=0.5*(fY1+fY3-(2*fY2))       ' solve coeff. a
            fB=0.5*(fY3-fY1)               ' solve coeff. b
            fX=fX-fB/(2*fA)                ' estimated location

            If fX>0 And fX<6 Then
                Debug CSRXY(16,1), %REAL1.6 fX
            Else
                Debug CSRXY(16,1), "OUTSIDE"
            End If
    Loop
End Sub
```

Ex. 10 --- PID Control Basics

This program shows how to employ the PID control on the Innoracer™. The PID parameters given in this program are just for tutorial purpose only. You may find your own PID parameters for different track conditions by trial and error.

```
Peripheral myM As RacerM1 @ 3    ' declare module ID
#DEFINE KP 6             ' PID parameters (0~255)
#DEFINE KI 0             '
#DEFINE KD 40            '
#DEFINE SCALE 0
#DEFINE CEN_SPD_R 210   ' right wheel central speed
#DEFINE CEN_SPD_L 210   ' left wheel central speed
#DEFINE ERR1 111    ' error values
#DEFINE ERR2 71
```

```
#DEFINE ERR3 45
#DEFINE ERR4 21
#DEFINE ERR5 9
#DEFINE ERR6 3
#DEFINE ERR7 0
#DEFINE ERR8 -3
#DEFINE ERR9 -9
#DEFINE ERR10 -21
#DEFINE ERR11 -45
#DEFINE ERR12 -75
#DEFINE ERR13 -111

Sub Stop()       ' subroutine to stop motors
   myM.BrakeDual()
End Sub

Sub Main()
   Dim Sensor As Byte          ' detection results
   Dim R, L As Integer         ' right/left wheel speed
   Dim Integral As Integer     ' Integral of errors
   Dim Derivative As Integer   ' derivative of errors
   Dim Err, PreErr As Integer  ' error and previous error
   Dim Out As Integer          ' result of PID calculation
   Dim Control As Integer      ' PID control values

   Out = 0              ' initial values
   Integral = 0         '
   PreErr = 0           '

   Pause 1000           ' wait for one second
   Do                   ' infinite Loop
      Sensor = Readport(0) And &B01111111  ' read port 0

      Select Case Sensor    ' error look-up table
         Case &B0111111   :   Err = ERR1
         Case &B0011111   :   Err = ERR2
         Case &B1011111   :   Err = ERR3
         Case &B1001111   :   Err = ERR4
```

```
          Case &B1101111   :   Err = ERR5
          Case &B1100111   :   Err = ERR6
          Case &B1110111   :   Err = ERR7
          Case &B1110011   :   Err = ERR8
          Case &B1111011   :   Err = ERR9
          Case &B1111001   :   Err = ERR10
          Case &B1111101   :   Err = ERR11
          Case &B1111100   :   Err = ERR12
          Case &B1111110   :   Err = ERR13
          Case &B1111111         ' out of range
              Stop()              ' stop motors
              Goto FINISH         ' terminate the program
      End Select

      Integral = Integral + Err    'PID formula
      Derivative = Err - PreErr
      Out = (KP*Err) + (KI*Integral) + (KD*Derivative)
      PreErr = Err
      Control = Out >> SCALE

      R = CEN_SPD_R + Control ' adjust right wheel speed
      L = CEN_SPD_L - Control ' adjust left wheel speed

      If R>1024 Then         ' right wheel speed limit
          R = 1024           '
      Elseif R<-1024 Then    '
          R = -1024          '
      End If

      If L>1024 Then         ' left wheel speed limit
          L = 1024           '
      Elseif L<-1024 Then    '
          L = -1024          '
      End If

      myM.SetVelAB(L,R)      ' change speed
   Loop
FINISH:
```

```
End Sub
```

Ex. 11 --- PID Control Using RacerM1 (Digital Mode)

We practice the PID control in the precious program and now we start to use the unique built-in PID control feature of the RacerM1 module. The major advantage that we can get in using the RacerM1 module is to save our valuable BASIC Commander® time to handle other important tasks.

There are two modes available, one is the digital mode, which interprets all the infrared reflection intensity values as logic 0 or 1 and the other is the analog mode, which interprets all the infrared reflection intensity values as analog values with wider range. Let's start with the digital mode first.

```
Peripheral myM1 As RacerM1 @ 3      ' declare module ID
#DEFINE KP 6            ' set PID parameters (0~255)
#DEFINE KI 0            '
#DEFINE KD 40           '
#DEFINE PID_SCALE 0
#DEFINE IR_POWER 70     ' define IR threshold

#DEFINE MAX_SPD_L 1024  ' max/min/central speed settings
#DEFINE MAX_SPD_R 1024  ' for left and right motors
#DEFINE CEN_SPD_L 210   ' ranging -1024~1024
#DEFINE CEN_SPD_R 210   '
#DEFINE MIN_SPD_L -1024 '
#DEFINE MIN_SPD_R -1024 '

#DEFINE ERR1 10     ' error values ranging 0~127
#DEFINE ERR2 20     '
#DEFINE ERR3 32     '
#DEFINE ERR4 45     '
#DEFINE ERR5 70     '
#DEFINE ERR6 90     '

Sub InitM1()       ' initialize M1 parameters
   myM1.SetP(KP)
   myM1.SetI(KI)
```

```
    myM1.SetD(KD)
    myM1.SetScalar(PID_SCALE)
    myM1.SetIRThreshold(IR_POWER)
    myM1.SetSpdCtrlA(MIN_SPD_L,MAX_SPD_L)
    myM1.SetSpdCtrlB(MIN_SPD_R,MAX_SPD_R)
    myM1.SetStraight(CEN_SPD_L,CEN_SPD_R)
    myM1.SetErrScale(ERR1,ERR2,ERR3,ERR4,ERR5,ERR6)
End Sub

Sub Main()
    Dim bIr AS BYTE
    Debug CLS            ' clear Terminal Window
    InitM1()             ' initialize M1 parameters

    Do
        bIr=Readport(0)              ' track in the middle?
    Loop Until (bIr And &B1000)

    Pause 3000           ' wait for 3 seconds
    myM1.SpdCtrlOn(0)    ' start PID control

    Do       ' infinite Loop
    Loop
End Sub
```

Ex. 12 --- PID Control Using RacerM1 (Analog Mode)

As mentioned in the previous practice, there are two modes available, one is the digital mode, which interprets all the infrared reflection intensity values as logic 0 or 1 and the other is the analog mode, which interprets all the infrared reflection intensity values as analog values with wider range. Now we try the analog mode, which has a better resolution in locating the track. Let's check it out!

```
Peripheral myM1 As RacerM1 @ 3    ' declare module ID
#DEFINE KP 6          ' set PID parameters (0~255)
#DEFINE KI 0          '
#DEFINE KD 40         '
```

```
#DEFINE PID_SCALE 0    '
#DEFINE IR_MODE 1      ' analog IR sensing mode
#DEFINE IR_POWER 70    ' IR intensity
#DEFINE MAX_SPD_L 1024  ' max/min/central speed settings
#DEFINE MAX_SPD_R 1024  ' for left and right motors
#DEFINE CEN_SPD_L 210   ' ranging -1024~1024
#DEFINE CEN_SPD_R 210   '
#DEFINE MIN_SPD_L -1024 '
#DEFINE MIN_SPD_R -1024 '
#DEFINE ERR1 3         ' error values ranging 0~127
#DEFINE ERR2 9         '
#DEFINE ERR3 21        '
#DEFINE ERR4 45        '
#DEFINE ERR5 71        '
#DEFINE ERR6 111       '

Sub InitM1()          ' initialize M1 parameters
   myM1.SetP(KP)      ' set PID parameters
   myM1.SetI(KI)      '
   myM1.SetD(KD)      '
   myM1.SetScalar(PID_SCALE)
   myM1.SetIRMode(IR_MODE)         ' set IR sensing mode
   myM1.SetIRThreshold(IR_POWER)   ' set IR threshold

   myM1.SetSpdCtrlA(MIN_SPD_L,MAX_SPD_L)
   myM1.SetSpdCtrlB(MIN_SPD_R,MAX_SPD_R)
   myM1.SetStraight(CEN_SPD_L,CEN_SPD_R)

   myM1.SetErrScale(ERR1,ERR2,ERR3,ERR4,ERR5,ERR6)
End Sub

Sub Main()
   Dim bIr AS BYTE

   Debug CLS     ' clear Terminal Window
   InitM1()      ' initialize M1 parameters

   Do
```

```
      bIr=Readport(0)       ' track in the middle?
   Loop Until (bIr And &B1000)
   Pause 3000

   myM1.SpdCtrlOn(0)  ' start PID control
   Do                 ' infinite loop
   Loop
End Sub
```

Ex. 13 --- Using the 2-Axis Accelerometer

There is a two-axis accelerometer on the Innoracer™, which is used by the RacerP1 module to measure the x- and y-axis acceleration force to calculate the curve radius and direction for route memorization. This program shows the basics using the RacerP1 module.

```
Peripheral myP1 As RacerP1 @ 4      ' declare module ID
Sub Main()
   Dim iX, iY As Integer

   Debug CLS
   Debug CSRXY(1,1),"Acceleration values"
   Do
      myP1.GetG(iX,iY)      ' get X and Y axis acceleration values
      Debug CSRXY(1,2),"X: ",CSRXY(4,2),%DEC5R iX  ' display values
      Debug CSRXY(1,3),"Y: ",CSRXY(4,3),%DEC5R iY  '
   Loop
End Sub
```

Ex. 14 --- Route Memorization

Route memorization is an important feature for Innoracer™, so it can run as fast as possible on straight line. This program shows how to record the track information through the RacerP1 module. You may notice that we use two modules, namely RacerM1 and RacerP1 modules, through which both the PID control and route memorization, are executed at the same time under the control of BASIC

Commander®.

```
Peripheral myM1 As RacerM1 @ 3  ' declare module ID
Peripheral myP1 As RacerP1 @ 4  '

#DEFINE CROSS_TIME 20   ' time to detect intersection
#DEFINE KP 4            ' set PID parameters (0~255)
#DEFINE KI 0            '
#DEFINE KD 40           '
#DEFINE PID_SCALE 0     '
#DEFINE MAX_SPD_L 1024  ' max/min/central speed settings
#DEFINE MAX_SPD_R 1024  ' for left and right motors
#DEFINE CEN_SPD_L 210   ' ranging -1024~1024
#DEFINE CEN_SPD_R 210   '
#DEFINE MIN_SPD_L -1024 '
#DEFINE MIN_SPD_R -1024 '

#DEFINE ERR1 10        ' error values ranging 0~127
#DEFINE ERR2 20        '
#DEFINE ERR3 32        '
#DEFINE ERR4 45        '
#DEFINE ERR5 70        '
#DEFINE ERR6 90        '

Sub InitM1()          ' initialize M1 parameters
   myM1.SetP(KP)          ' set PID parameters
   myM1.SetI(KI)
   myM1.SetD(KD)
   myM1.SetScalar(PID_SCALE)

   myM1.SetSpdCtrlA(MIN_SPD_L,MAX_SPD_L)
   myM1.SetSpdCtrlB(MIN_SPD_R,MAX_SPD_R)
   myM1.SetStraight(CEN_SPD_L,CEN_SPD_R)

   myM1.SetErrScale(ERR1,ERR2,ERR3,ERR4,ERR5,ERR6)
End Sub

Sub InitP1()                 ' initialize P1 parameters
```

```
    myP1.SetCrossTime(CROSS_TIME)   ' set detection time
    myP1.AutoBeep(1)                ' recording beeps on
End Sub

Sub Main()
    Dim Status As Byte
    Dim bIR As Byte

    InitM1()           ' initialize M1 parameters
    InitP1()           ' initialize P1 parameters

    Do
        myM1.GetIR(bIr)             ' track in the middle?
    Loop Until (bIR And &B1000)
    myP1.StartRec(1)           ' start recording

    Do
        myP1.GetRecStatus(Status)   ' recording started?
    Loop Until Status=1

    myM1.SpdCtrlOn(0)              ' start PID control

    Do
        myP1.GetRecStatus(Status)   ' start mark detected?
    Loop Until Status=2

    Do
        myP1.GetRecStatus(Status)   ' stop mark detected?
    Loop Until Status=0

    myP1.StopRec()       ' stop recording
    myM1.BrakeDual()    ' brake both wheels
End Sub
```

Ex. 15 --- Retrieving Route Information

In previous exercise, we recorded all the sections of route information. In this

program, we display all the sections of route information in the Terminal Window. If you encounter a route memorization problem, this is a very useful debug tool to identify where the problem is.

```
Peripheral myP1 As RacerP1 @ 4     ' declare module ID
Sub Main()
   Dim i As Byte                    ' route index
   Dim bDir As Byte                 ' direction of curve
   Dim bSecCnt As Byte              ' number of sections recorded
   Dim iGx, iGy As Integer          ' x and y acceleration values
   Dim dwLenR, dwLenL As Dword      ' distance of sections
   Dim dwRad As Dword               ' radius of curves

   myP1.GetSecCnt(bSecCnt)    ' read the number of sections
   For i=0 To bSecCnt         ' display section information
      Debug "Sec.: ", %DEC3R i, CR
      myP1.GetSecLen(i, dwLenL, dwLenR)
      Debug "Right Wheel Dist.: ", %DEC9R dwLenR, CR
      Debug "Left Wheel Dist.: ", %DEC9R dwLenL, CR
      myP1.GetSecAvgG(i, iGx, iGy)
      Debug "X-axis acc. (average): ", %DEC5R iGx, CR
      Debug "Y-axis acc. (average): ", %DEC5R iGy, CR
      myP1.GetSecMaxG(i, iGx, iGy)
      Debug " X-axis acc. (max.): ", %DEC5R iGx, CR
      Debug " Y-axis acc. (max.): ", %DEC5R iGy, CR
      myP1.GetSecRadius(i, bDir, dwRad)
      Debug "Direction of curve: ", bDir
      Debug "Radius: ", %DEC9R dwRad,CR,CR
   Next
End Sub
```

Ex. 16 --- Acceleration

We know how to record the information of all the sections of the route. Now we can start to use this information to speed up our Innoracer™. There are many different approaches or strategies to speed up the Innoracer™. In this program, we learn the basics of acceleration according to the route information. The Innoracer™ starts to

accelerate after the Start mark is detected and stops after a given distance is reached.

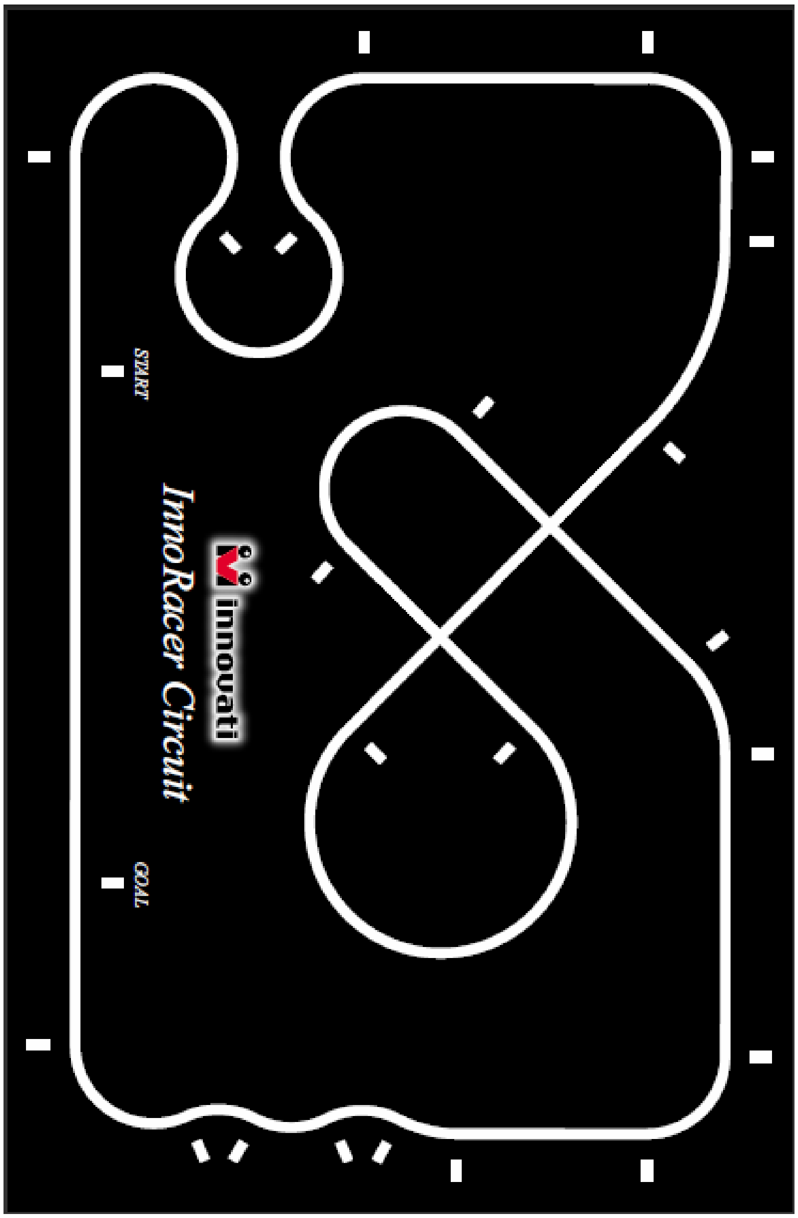
```
Peripheral myM1 As RacerM1 @ 3  ' declare module ID
Peripheral myP1 As RacerP1 @ 4  '

#DEFINE CROSS_TIME 20   ' time to detect intersection
#DEFINE KP 4            ' set PID parameters (0~255)
#DEFINE KI 0            '
#DEFINE KD 48           '
#DEFINE PID_SCALE 0     '
#DEFINE MAX_SPD_L 1024  ' max/min/central/acc speed settings
#DEFINE MAX_SPD_R 1024  ' for left and right motors
#DEFINE CEN_SPD_L 210   ' ranging -1024~1024
#DEFINE CEN_SPD_R 210   '
#DEFINE MIN_SPD_L -1024 '
#DEFINE MIN_SPD_R -1024 '
#DEFINE ACC_SPD_L 450   '
#DEFINE ACC_SPD_R 450   '
#DEFINE STOP_TACH 100   ' distance before start to brake
#DEFINE ERR1 10         ' error values ranging 0~127
#DEFINE ERR2 20         '
#DEFINE ERR3 32         '
#DEFINE ERR4 45         '
#DEFINE ERR5 70         '
#DEFINE ERR6 90         '

Sub InitM1()            ' M1 module initialization
   myM1.SetOutsideMode(2)   ' set out-of-track behavior
   myM1.SetP(KP)          ' set PID parameters
   myM1.SetI(KI)
   myM1.SetD(KD)
   myM1.SetScalar(PID_SCALE)

   myM1.SetSpdCtrlA(MIN_SPD_L,MAX_SPD_L)
   myM1.SetSpdCtrlB(MIN_SPD_R,MAX_SPD_R)
   myM1.SetStraight(CEN_SPD_L,CEN_SPD_R)
```

```
    myM1.SetErrScale(ERR1,ERR2,ERR3,ERR4,ERR5,ERR6)
End Sub

Sub InitP1()          ' P1 module initialization
    myP1.SetCrossTime(CROSS_TIME)    ' set detection time
End Sub

Sub Main()
    Dim Status As Byte
    Dim IR As Byte
    Dim bCnt1 As Word
    Dim LenR,LenL As Word

    bCnt1 =0
    InitM1()    'initialize M1
    InitP1()    'initialize P1
WAIT_BUTTON:
    Do
        Button(16,0,255,255,bCnt1,1,RACE) ' button pressed?
    Loop
RACE:
    Do
        myM1.GetIR(IR)             ' track in the middle?
    Loop Until (IR And &B1000)
    Pause 2000

    myP1.StartRec(0)         ' start recording
    Do
        myP1.GetRecStatus(Status) ' recording started?
    Loop Until Status=1

    myM1.SpdCtrlOn(0)            ' start PID control

    Do
        myP1.GetRecStatus(Status) ' start mark detected?
    Loop Until Status=2

    myM1.SetStraight(ACC_SPD_L,ACC_SPD_R)  ' high speed
```

```
    Do
        myP1.GetTotalLen(LenL,LenR)
    Loop Until LenL>STOP_TACH

    myM1.BrakeDual()      ' brake
    myP1.StopRec()        ' stop recording
    Goto WAIT_BUTTON
End Sub
```

Appendix B --- Sample Course Map

This is a sample track. The actual size is 150 cm x 230 cm. There could be different racing games with similar rules. Please refer to their official document and modify the course and program accordingly.



Appendix C --- Revision History

Revision	Date	Changes
1.4	Jan. 16, 2011	New Release (English Edition)
1.5	June 22, 2011	1. Correct Command Format Description Error: bStatus = TACHInDual(TACHL, TACHR) GetSecLen(Num, LengthL, LengthR) GetCurSecTACH(LengthL, LengthR) GetTotalLen(LengthL, LengthR) 2. Related Correction in Tutorial Ex 15 and Ex16.